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Cross-layer Rate Adjusted Congestion Controlled Protocol for Wireless Multimedia Sensor Networks

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Abstract: ***Wireless Multimedia Sensor Networks (WMSNs) consists of set of sensor nodes which can capture multimedia data as well as scalar data from the target region and transmit to the base station. The type and nature of traffic generated in WMSNs leads to congestion and it can cause substantial loss of data packets, reduced throughput and wastage of energy. In order to overcome the challenge, a cross layer protocol which adjusts the rate of transmission is proposed in this paper. As per the information provided by the MAC layer regarding buffer availability and channel traffic condition, the proposed protocol adjusts the channel access along with transmission rate of the nodes. The simulation results reveal that the proposed protocol performs better than the existing protocols with respect to packet loss, throughput and energy.***

Keywords:. Congestion, Multimedia, Protocol, Sensor.

I. INTRODUCTION

Micro Electro Mechanical Systems (MEMS) technologies along with communication protocols [1] provides great opportunity for wide spread applications of Wireless Sensor Networks (WSNs). Due to the availability of low cost hardware like CMOS (Complementary Metal Oxide Semiconductor) devices, the capability of sensor nodes are extended to emerge a new dimension of WSNs named as Wireless Multimedia Sensor Networks (WMSNs). WMSNs consist of a large number of wireless sensor nodes bearing the role for sensing, receiving and processing of images, audio and video streams in addition to scalar data [2]. Nodes are battery operated which may lose power over a period of time involving in the process of transmission, computation and reception and make the node of no use. To extend the life of the entire network, a large number of these low cost devices are deployed in the network i.e. density of nodes are maintained high.

The challenges faced by WMSNs are because of resource constraints like limited energy, processing capacity, bandwidth and memory. Multimedia processing involves high volume of traffic and complex computations and when it gets associated with this resource constrained nodes, it leads to congestion and reduces the Quality of Service (QoS). So the target is to develop protocols or techniques to extend the lifetime of the networks and provides the required QoS [3].

Generally WMSNs deal with more amount of traffic and the data packets are stored in the buffer of the nodes to access the shared medium. This leads to congestion in the network. When the network becomes congested, data packets are dropped because of limited buffer capacity of the nodes and hence results in packets loss which reduces the throughput and also leads to wastage of energy. So congestion control becomes a challenge in WMSNs.

In traditional techniques for congestion control, the nodes decrease their rate of transmission rate in the transport layer to handle congestion in the network and as a result a reasonable network throughput could not be maintained. Also the existing congestion control protocols in transport layer hardly consider the importance of energy efficiency. Control signals used for congestion control and retransmission of lost data packets causes more energy consumption and reduces the network life time. Moreover because of multi hop and simultaneous routing, data packets originating closer to the congested nodes are likely to have higher chance of getting undelivered or dropped and it is commonly called as unfairness problem.

Usually the traffic in the network could be periodic or bursty in nature and in each case, the data flows in the direction of sink or base station node from the source nodes which may cause congestion. The situation becomes more complicated when concurrent data flows over various channels and interact with each other. As the density of the nodes is high in these networks, congestion might occur frequently and affect the energy efficiency and QoS of WMSNs.

Majority of the protocols for congestion control has three units like detection, notification and control unit. Detection unit detects congestion and different techniques for detecting congestion including packet inter arrival time of packets [4], service time of packets [5] , length of the queue [6][7], load on the medium [8] or a mixture of all of these [9] exist. Notification unit is responsible for notifying the congestion signal when it is detected. This could be achieved in two different ways namely implicit and explicit notification. In the case of implicit notification, the notification information is piggybacked in the packet headers and in case of explicit notification an extra packet is transmitted mentioning congestion information to other connected nodes.

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The rate control segment is responsible for avoiding congestion by adopting some mechanism to control the rate of data packet transmission. Also there exist techniques to deal with congestion through data processing and routing optimization [10].

The congestion control mechanism usually involves detection of congestion followed by adjustment of rate of transmission to control congestion. Congestion detection always happens at the receiving node by observing the ratio of incoming packets with outgoing packets along with the buffer status of the node. To address the congestion issue, an efficient data rate adjustment mechanism is required to avoid congestion

II. RELATED WORK

CODA (Congestion detection and avoidance) [8] consists of three phases. The channel and the queue has a vital role in the detection of congestion within the network. Channel is periodically sampled and compared with utilization and if there is presence of congestion, then notification message is broadcasted. Upon getting the notification, the source nodes adjust their rate of transmissions. However CODA introduces the limitations like packet loss, low link utilization, high delay and high error rates. Also the backpressure message introduces overhead which leads to inefficient energy and bandwidth utilization. The authors in [4] proposed PCCP to addresses congestion. PCCP consist of mainly detection unit, notification unit and rate adjustment unit. It considers packet service time and inter arrival time of packets for congestion detection. The notification information is always piggybacked along with the data packets for information of other nodes. Major drawback of PCCP is unfairness. It is so because, during absence of congestion, the packet generation and rate of scheduling are increased without consideration of priorities of the nodes and during congestion, the rate of transmission is reduced all along the network.

Authors of [11] proposed a priority based congestion control protocol and the traffic is divided into different classes based on their priority. It adopts a technique like random early detection (RED). The lengths of the queue for the nodes are compared with the queue length threshold value to detect the congestion level. It applies the technique of rate adjustment and informs the other nodes about the updated transmission rate. It suffers from limitations like the threshold values need to be adjusted on regular basis to have correct congestion level.

A scalable technique named as CCF [5] is developed which considers packet service time to detect congestion. Nodes compute the rates at which packets to be sent, divide them among their children and then update the rate. It also makes use of implicit notification technique and rate adjustments are done based on service rate and available child nodes. CCF achieves fairness but leads to decreased throughput during the time when few nodes remain inactive.

The protocol proposed in [12] involves activities like topology management, hierarchical path maintenance, detection of alternate path and managing unused nodes. Minimum Spanning Tree concept is used to preserve network connectivity.

The authors of [13] proposed resource congestion control protocol which considers the multimedia data specifying the priority of frames like I-frames for the quality of the video. However resource control may not be feasible option protocols for reducing congestion in WMSNs.

III. PROTOCOL DESIGN

Network Model and Assumptions:

In this proposed approach we assume the random deployment of the nodes in the region and also the nodes are static in nature. The nodes capture different event information and transmit the same to base station or sink. Figure-1 depicts the model of the network with multi-hop routing.

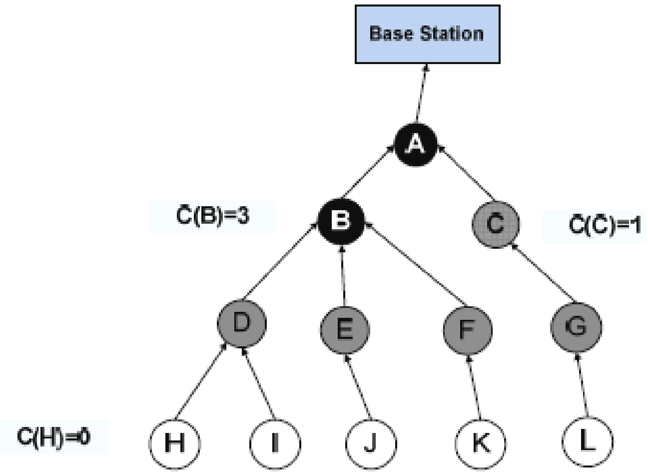

Figure 1: Network model

The nodes adopt Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) approach for transmission of packets in the MAC layer. During packet forwarding towards the sink node, each sensor node transmits the captured data along with the received data from its children nodes and hence a sensor node acts as both source and relay node. The node which transmits data packets in the direction of the destination node is known as a child and its immediate upstream node is known as the parent node. The link within parent and child node is bidirectional in nature i.e. the child and parent nodes are within the range of transmission of each other. Let the number of children of parent node K is C(K) . In Figure-1, node A has 2 children, B has 3, and node L does not have any child and there exist a path from each node to the base station. Nodes like A and B in Figure 1 has a high probability of getting congested because the entire traffic under these nodes as well as of its own, need to travel through these nodes. Other parent nodes may also suffer from congestion and the nodes having no children have the least possibility of congestion.

The proposed algorithm is a cross layer one and is executed in the network layer. It interacts with MAC layer for congestion control management. Data generated from application layer in case of a source nodes and data received from child nodes in case of relay nodes, move through the network layer.

The proposed Protocol:

It is a cross layer and energy efficient protocol for minimizing congestion by controlling transmission rates at the sensor nodes. When congestion occurs, data packets are delayed and dropped because of overflow of the buffer at the nodes. The nodes are aware of the size of the queue which plays a vital role in congestion detection.

The proposed protocol assigns higher data rates based on the status of nodes. The protocol operates in three stages such as detection, notification and rate adjustment.

Congestion Detection:

It is the initial phase of the proposed congestion control scheme which detects whether congestion is there or not in the network. If congestion is detected, then a notification will notify every other node the congestion information and hence the nodes adjust their respective transmission rates to deal with the situation.

Congestion detection is performed by observing the queue of the nodes. It considers a lower threshold (THlow) and another higher threshold (THhigh) value for the computation of congestion level. If the observed queue length found to be less than THlow , then there is no congestion at the node and the regular activity of receiving packets and adding them into queue continues. However if the observed queue length found to be more than THhigh , then congestion is there at the node and hence the received packets are marked. If the observed average queue length is within THlow and THhigh , then congestion is likely to be there and received packets are dropped depending on the probability of congestion. So by the use of this approach congestion could be detected before the packets are lost.

The threshold values are determined based on the outgoing rate (Rout), the incoming rate (Rin) and the size of the queue (Q) and they are:

$$THlow = \frac{R_{out}}{MAX(R_{in})} x\ Q \qquad (1)$$

$$THhigh = \frac{R_{out}}{MIN(R_{in})} x\ Q \qquad (2)$$

The congestion factor (CF) is defined as:

$$CF = \begin{cases} 0, Q \le TH_{low} \\ \frac{Q - TH_{low}}{TH_{high} - TH_{low}}, TH_{low} \le Q \le TH_{high} \\ 1, Q > TH_{high} \end{cases} \qquad (3)$$

The output of the congestion factor (CF) is sent to the congestion notification unit which in turn notifies the other nodes regarding the congestion level at that node. It allows the nodes to adjust their respective rate of transmission with respect to the congestion level

Congestion Notification:

When congestion occurs, the nodes around the vicinity need to be notified regarding congestion in order to overcome the issue of packet loss and the delay in the queue of the buffer. The congestion notification is sent implicitly without any extra overhead to send it as a separate packet. It is achieved through congestion notification message being piggybacked in the acknowledgement packet headers. As implicit notification does not contribute to the traffic in the network, it is the preferred approach which is an energy efficient approach in comparison to explicit notification. Another advantage is to have the congestion notification can be overheard by other nodes in the periphery and become aware of the congestion notification without extra overhead. The congestion notification message incorporates node's congestion factor (CF) and also the number of children C(K). The downstream node's buffer occupancy level information is incorporated in the CF message to the upstream node. After receiving the congestion notification message the source nodes adjust their transmission rates to overcome the problem of congestion.

Rate Adjustment:

The rate adjustment algorithm is a distributed one which gets executed in all nodes in the network except the sink node. While processing the congestion notification signals from the downstream nodes, the upstream node also considers its own congestion status. The rate adjustment algorithm affects performance of the network in the direction of improved throughput and also transmission fairness. The time when the upstream node receive congestion notification signal from the downstream nodes, they execute the algorithm "Congestion Processing Algorithm" and behave accordingly.

Algorithm: Congestion Processing

Symbols used:
Buffer occupancy level of the node (B),
Buffer occupancy level of the downstream node (B'),
Higher buffer occupancy threshold level (THhigh),
Channel contention window (W),
Maximum size of channel contention window (Wmax),
Rate of Transmission (R),
Maximum rate of transmission (Rmax).

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1: Initialize the channel contention window: W = Wmax
2: If B' > THhigh  && B > THhigh
        R ← 0.25 × R
        W = 0.5 × (5 × W × B +0.1×W× 1/B')
3: End if
4: If B' > THhigh && B ≤ THhigh
        R ← 0.5 ×R
        W = 5× W × B'
5: End if
6: If B' ≤ THhigh && B > THhigh
        R ← Min (0.5×R, R+0.5 × (Rmax - R))
        W = Min(10×W×B', 0.1×W× 1/B)
7: End if
8: If B' ≤ THhigh && B < THhigh
        R ← R + 0.5 × (Rmax – R)
        W = 10× W × B'
9: End if
```

This approach takes care of downstream node's congestion information and the status of the local node. It also avoids frequently relaying congestion information of downstream nodes which would otherwise cause energy waste. When B' ≤ THhigh and B > THhigh , it indicates that congestion occurs at the local node only and not in the direction of downstream node.

The node will only deal with the local congestion without relay. In case of congestion, the local node will reduce its data transmission rate and reduce channel contention window to increase channel access probability.

When there is no local congestion, if B' > THhigh, indicating that congestion occurs in the downstream node, it will increase channel contention window by W =5 × W × B' and reduce the data transmission rate as R =0.5 × R; otherwise it will linearly increase the data transmission rate as
R = R + 0.5 × (Rmax – R).

The protocol exploits the AIMD strategy for transmission rate adjustment with an objective to relieve local congestion as soon as possible while keeping stable network throughput.

IV. RESULT ANALYSIS

The proposed protocol "Cross-layer Rate Adjusted Congestion Control" (CRACC) have been simulated using NS2 simulator. The performance is analyzed with respect to average end to end delay, average packet loss, throughput and average energy consumption of source nodes.

The performance of the protocol has been compared with the recent similar protocols in the same domain namely TMCC[14] and PQACC[15]. Table-1 summarizes the parameters used for simulation.

Table 1: Parameters used

No. of sensor nodes	30
Topography size	500 X 500 square meters
Node transmission radius	40 meters
MAC layer	IEEE 802.11
Simulation duration	800 seconds
Traffic type	CBR
Size of data packets	200 Bytes
Initial energy	100 Joules
Bandwidth	2MB
Rate of Transmission	10,15,20,25,30,35 and 40 packets / second

Total 30 numbers of nodes are randomly deployed in a region of 500 square meters. The network bandwidth is 2Mbps and the transmission rate is 1Mbps. The maximum threshold of buffer is set to 75 percent and minimum is 25 percent for a total buffer capacity of 500 packets. The channel contention window size is ranged from 1 to 63 like SMAC protocol. The initial energy of sensor nodes is 100J. The total buffer size is 500 data packets. The size of every packet is 200 Bytes. The load is varied starting from 10 packets per second to 40 packets per second with a gap of 5 packets.

The following metrics for performance evaluation have been considered and compared with the existing protocol.

1. Average end to end delay.
2. Average throughput.
3. Average energy consumption of the nodes.
4. Average number of packet drops.

1. Average end to end delay:

End to end delay means the overall time difference of data packets since it is transmitted from source and the time of reception at the destination node.

It is quite evident from the figure 2 is that as the load increases, due to more number of data packets the traffic gets congested and hence the average end to end delay also increases. However as per the said algorithm, the nodes adjust their rate of transmission when congestion occurs and thereby rate of increase in the delay factor gets reduced. In comparison to the protocols TMCC and PQACC, the proposed protocol CRACC performs better with a marginal difference. This is mainly because of use of implicit notification and rate adjustment using AIMD approach. Moreover the protocol PQACC performs better than TMCC due to the inherent probabilistic computation of congestion threshold value.

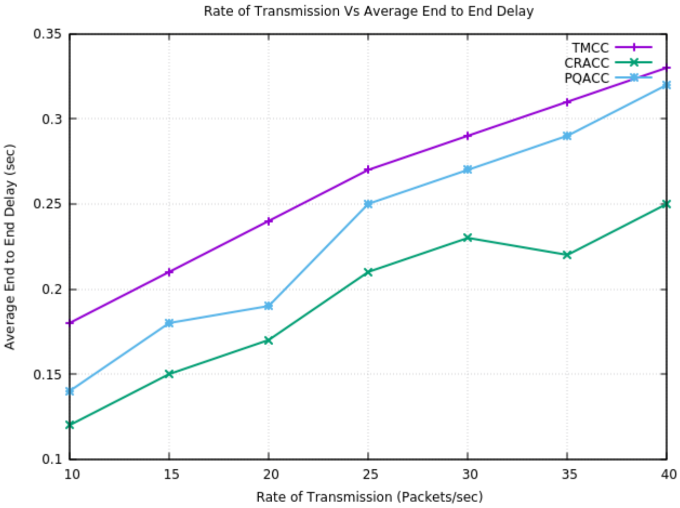

Figure 2: Rate vs. Average end to end delay

2. Average throughput:

While analyzing the throughput factor for the protocols it is observed that there is a common pattern followed in all these compared protocols as shown in figure 3. There is a steady increase in throughput when there is increase in rate of transmission. This is because of the congestion controlling mechanism adopted in all these protocols to increase the packet delivery ratio and throughput. However among all these the proposed protocol CRACC performs better as compared to the other two protocols namely TMCC and PQACC.

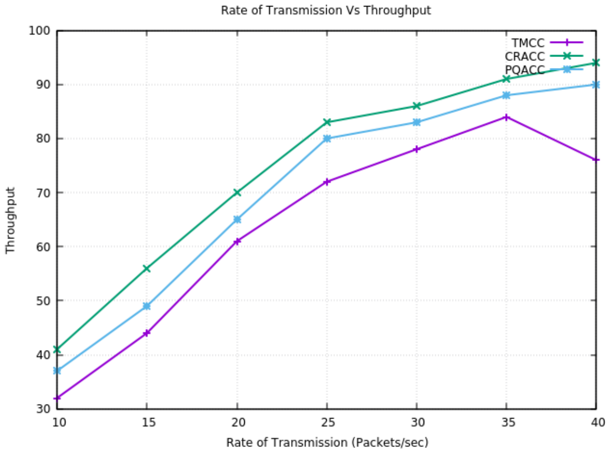

Figure 3: Rate vs. Average Throughput

3. Average energy consumption of the nodes:

Energy gets consumed for each and every operation of the nodes. So the less is the involvement in the communication process, less is the energy consumed to improve upon the life time of the node and the network. As a result it is observed from figure 4 that the proposed protocol CRACC consumes less amount of energy per node on an average in the entire network due to the factor of controlling congestion. Due to that there is less number of packet drops and retransmission at every node and the average energy is consumption is computed by considering the average across all the nodes in the network. This is one of the desired parameter in achieving higher level of QoS in WMSNs. Moreover because of implicit notification message also leads to reduced energy consumption.

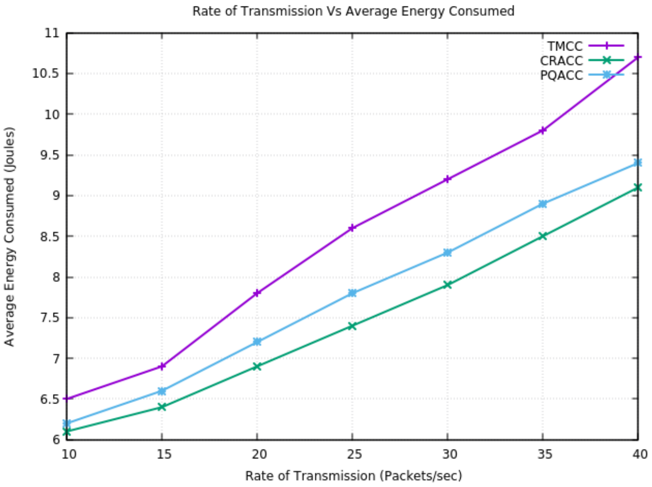

Figure 4: Rate vs. Average energy consumed

4. Average number of packet drops:

Figure 5 depicts the comparison of number of dropped packets for the three protocols. The proposed protocol performs better than the other two protocols as shown in the figure. This is due to the fact that in the proposed protocol, because of rate adjustment the number of dropped packets is considerably low as compared to TMCC and PQACC.

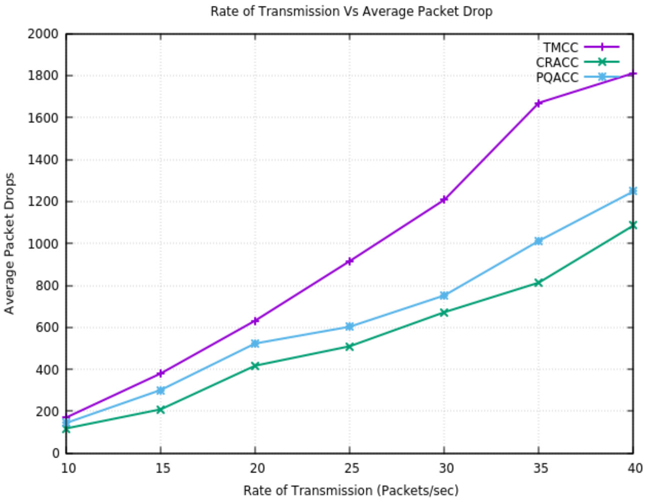

Figure 5: Rate vs. Average packet drop

V. CONCLUSION

An approach to resolve the congestion issue in WMSNs, has been proposed based on traffic and queue management. The objective of the approach is to avoid congestion and manage traffic with minimal energy consumption.

The simulation results confirm that the proposed approach improves average end to end delay, throughput, energy consumption and lifetime as compared to TMCC and PQACC methods.

REFERENCES

1. Karl H. and Willig A., Protocols and Architectures for Wireless Sensor Networks, Wiley, 2006.
2. Chen, Y.L. and Lai, H.P. (2012) Priority-Based Transmission Rate Control with a Fuzzy Logical Controller in Wireless Multimedia Sensor Networks. Computers and Mathematics with Applications, 64, 688-698.
3. Akyildiz, I.F., Su, W., Sankarasubramaniam, Y. and Cayirci, E. (2002) Wireless Sensor Networks: A Survey. Computer Networks, 38, 393-422.
4. C. Wang, B. Li, K. Sohraby, M. Daneshmand, and Y. Hu, “Upstream congestion control in wireless sensor networks through crosslayer optimization,” IEEE J. Sel. Areas Commun., vol. 25, no. 4, pp. 786–795, May 2007.
5. C. T. Ee and R. Bajcsy, “Congestion control and fairness for many-to-one routing in sensor networks,” in Proceedings of the 2nd international conference on Embedded networked sensor systems, 2004, pp. 148–161.
6. B. Hull, K. Jamieson, and H. Balakrishnan, “Mitigating congestion in wireless sensor networks,” in Proceedings of the 2nd international conference on Embedded networked sensor systems SenSys ’04, 2004, p. 134.
7. C.Y. Wan, S. B. Eisenman, A. T. Campbell, and J. Crowcroft, “Siphon: Overload Traffic Management using Multi Radio Virtual Sinks in Sensor Networks,” Proc. 3rd Int. Conf. Embed. networked Sens. Syst. SenSys ’05, vol. 3, p. 116, 2005.
8. C.Y. Wan, S. B. Eisenman, and A. T. Campbell, “Energy efficient congestion detection and avoidance in sensor networks,” ACM Trans. Sens. Networks, vol. 7, no. 4, pp.1–31, 2011.
9. J. Kang, Y. Zhang, and B. Nath, “TARA: Topology aware resource adaptation to alleviate congestion in sensor networks,” IEEE Trans. Parallel Distrib. Syst., vol. 18, no. 7, pp.919–931, 2007.
10. H. Yuan, N. Yugang, and G. Fenghao, “Congestion control for wireless sensor networks: A survey,” in The 26th Chinese Control and Decision Conference (2014 CCDC), 2014, pp. 4853–4858.
11. M. Yaghmaee and D. Adjeroh, “A New Priority Based Congestion Control Protocol for Wireless Multimedia Sensor Networks,” Int. Symp. a World Wireless, Mob. Multimed. Networks, 2008. WoWMoM 2008, pp. 1–8, 2008.
12. C. Sergiou, V. Vassiliou, and A. Paphitis, “Hierarchical Tree Alternative Path (HTAP) algorithm for congestion control in wireless sensor networks,” Ad Hoc Networks, vol.11, no. 1, pp. 257–272, 2013.
13. S. Mahdizadeh Aghdam, M. Khansari, H. R. Rabiee, and M. Salehi, “WCCP: A congestion control protocol for wireless multimedia communication in sensor networks,” Ad Hoc Networks, vol. 13, no. PART B, pp. 516–534, 2014.
14. Golgiri R and Javidan R, “ TMCC: An Optimal Mechanism for Congestion Control in Wireless Sensor Networks”, International Journal of Advanced Computer Science and Applications, (IJACSA),Vol. 7, No. 5, 2016,pp.454-460.
15. M. Mayandi and K. V. Pilla, “Probabilistic QOS Aware Congestion Control in Wireless Multimedia Sensor Networks “, Circuits and Systems, 7, pp 2081-2094, 2016.

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